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RESULTS OF TESTS ON A 0.111-SCALE SPACE SHUTTLE

VEHICLE SIMULATED ELEVON/ELEVON GAP

HEAT TRANSFER MODEL (53-0) IN THE AMES RESEARCH

CENTER 3.5-FOOT HYPERSONIC WIND TUNNEL (OH44)

by

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by

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WIND TUNNEL TEST SPECIFICS:

Test Number:	ARC 3.5 Ft. HWT-177
NASA Series Number:	OH44
Model Number:	53-0
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Occupancy Hours:	80

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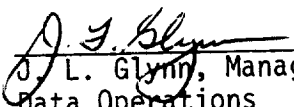Downey, Ca. 90241

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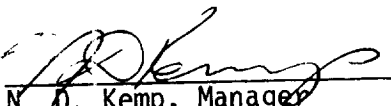Moffett Field, Ca. 94035

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RESULTS OF TESTS ON A 0.111-SCALE SPACE SHUTTLE VEHICLE

SIMULATED ELEVON/ELEVON GAP HEAT TRANSFER MODEL (53-0) IN THE

AMES RESEARCH CENTER 3.5-FOOT HYPERSONIC WIND TUNNEL (OH44)

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ABSTRACT

Aerodynamic heating in gaps is an area of major concern on the Space
Shuttle Orbiter since it is not amenable to treatment solely by analysis.
Model 53-0 was tested to evaluate the effect of elevon deflection, gap
geometry, and boundary layer state on elevon/elevon gap heating. Testing
was conducted in the Ames Research Center 3.5-Foot Hypersonic Wind Tunnel
at a nominal Mach number of 5.1 and the model at zero angles of attack, yaw,
and roll.

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INDEX OF MODEL FIGURES

Symbol	Computer Symbol	Definition
b		thickness of model skin
C		specific heat of model skin material, BTU/lb mass
C_0, C_1, C_2		constants in curve fit for C over model wall temperature range
c_p		specific heat at constant pressure of air stream (perfect gas value), BTU/lb
CHAN	CHAN	recording-system channel
H_{aw}	HAW	adiabatic wall enthalpy, BTU/lb mass or joule/kilogram
H_t	HT	free-stream total enthalpy, BTU/lb mass or joule/kilogram
H_{w_i}	HW	enthalpy based on model wall temperature for given T/C location at initial time, BTU/lb mass or joule/kilogram
h	H	heat-transfer coefficient at model wall for given T/C location
h_s	HS	stagnation-point heat-transfer coefficient for reference sphere
h/h_s(X.XXX)	H/HS(X.XXX)	ratio of model heat-transfer coefficient to heat-transfer coefficient of reference sphere for H_{aw}/H_t= X.XXX (1.0, 0.9, 0.85)
L	LENGTH	model reference length, inches
M_∞	MACH	free-stream Mach number
P_t	PT	free-stream total pressure, PSI or atmospheres
q_i	Q	heat-transfer rate at model wall for given T/C location at initial time, BTU/ft^2 sec

Symbol	Computer Symbol	Definition
$\dot{q}_s$	QS	stagnation-point heat-transfer rate for reference sphere at initial time
R_s	RS	reference sphere radius at model scale equivalent to 0.305 m (1 ft) for full-scale vehicle
Re_∞/ft	RE/FT	free-stream Reynolds number per foot; also, per meter
Re_∞,L	REL	free-stream Reynolds number based on model reference length, L
$St(X.XXX)$	$ST(X.XXX)$	Stanton number based on free-stream flow conditions and the model heat-transfer coefficient for H_{aw}/H_t= X.XXX (1.0, 0.9, 0.85)
T		temperature, degrees Rankine/Fahrenheit
T_t	TT	free-stream total temperature, degrees Rankine/Fahrenheit
T_{w_i}	TW	model wall temperature for given T/C location at initial time, degrees Rankine/Fahrenheit
T/C	T/C	thermocouple
t	T	time, sec.
t_i	TIME	initial time (before model insertion into flow) extrapolated from $f(T_w)$ vs time, sec.
V	V	velocity, ft/sec
W		density of model skin material, lb mass/ft^3
ρ	RHO	viscosity of air, $\dfrac{lb - sec}{ft^2}$
μ	MU	density of air, slugs/ft = $\dfrac{lb - sec^2}{ft^4}$
T_{aw}'		perfect gas adiabatic wall temperature
C_{aw}'		specific heat calculated at T_{aw}'

NOMENCLATURE (Concluded)

SUBSCRIPTS

aw	adiabatic wall
i	initial value before model insertion into tunnel flow
PG	perfect gas (calorically and thermally perfect gas)
s	reference sphere
t	free-stream total condition
w	wall
∞	free-stream
1	conditions upstream of shock
2	conditions downstream of shock

CONFIGURATIONS INVESTIGATED

The model consists of a scale representation of the wing/elevon gap geometry inserted in the existing basic model 15-0 flat plate carrier. This stainless steel flat plate carrier is 2 inches thick, 27 inches wide, and 60 inches long with a wedge leading edge. The carrier is designed to accept 24-inch wide inserts with lengths of 6 or 12 inches. This carrier can be seen in Figure 1, which shows the elevon installed at a station 24 inches aft of the carrier leading edge. The elevon can be shifted in the carrier all the way aft to station 48. Flat plate inserts are installed forward and aft of the elevon. This model has been designated as model 53-0.

The use of existing instrumented flat plate inserts forward of the elevon permitted heating rates to be established upstream of the elevon. Thermocouples were used on thin skin areas of the elevon to establish heating. All instrumentation leads were routed under the flat plate inserts to the aft end of the carrier and then down into the sting.

Following completion of the elevon/wing gap test OH15, the model was modified to permit evaluation of the effect of elevon/elevon gap width and gap geometry on the heating in the elevon/elevon gap. The elevon is basically made up to 3 major assemblies: cove, base plate, and deflectable flap. The flap is mechanically attached to a hinge rod, which is part of the base plate. A continuous hinge rod spacer prevents air flow entering the elevon/wing gap from flowing around the hinge and out under the flap. Flow stoppers prevent spanwise flow in the elevon/wing gap. Brackets

are installed under the flap to obtain elevon deflections from 0° to 25° in 5° increments. Different deflections can be obtained on the two flaps to permit the evaluation of differential deflections.

The left hand flap was constructed so that the elevon/elevon gap could be configured to any one of the following widths: 0.056", 0.222", and 0.666". Separate 20° and 40° scarf ends were provided for the left hand flap to evaluate the effect of scarfing. Thin skin inserts were prepared for the end of the right hand flap and for the 20° and 40° scarfed ends of the left hand flap.

The 0.056" gap extends all the way forward to the flap leading edge. When the model is configured for the wider gaps (with and without scarfing), the wider gap does not start until a point just aft of the hinge line is reached. Thus, all configurations have an 0.056" gap from the flap leading edge to the hinge line. Then for the 0.222" and 0.666" gaps, the wider gap starts with an abrupt discontinuity at a point 5.0" forward of the flap trailing edge.

INSTRUMENTATION

The model is constructed of 17-4 PH stainless steel. Thin skin inserts made of 17-7 PH stainless steel are used on the cove and flap for instrumented areas. For this test series, the model was instrumented with a total of 70 chromel-constantan thermocouples spot-welded to the skin. These thermocouples are located in two parallel rows on either side of the model ₵ on the elevon and cove. Thermocouples (T/C's) 101 thru 150 are located on the elevon and T/C's 151 - 170 are located on the cove.

Existing instrumented flat plate inserts (from model 15-0) were used forward of the elevon assembly. These inserts are fabricated of 17-4 PH stainless steel and have a single row of thermocouples along the model ₵. Six T/C's were located on the top of the right hand flap in two rows between the inboard end and the first chordwise row of T/C's to evaluate the spanwise heating distribution. These are T/C's 171 - 176. A total of 49 additional T/C's (T/C's 177 - 225) were located on the thin skin insert which formed the end of the right hand flap. Twenty thermocouples were placed on each of the thin skin inserts for the scarfed ends of the left hand flap. T/C's 251 - 270 are on the 20° scarf and T/C's 271 - 290 are on the 40° scarf. Eight additional T/C's are available from the flat plate inserts located upstream of the elevon. The two instrumented inserts (T/C's 1 - 5, 15, 18, and 19) were used upstream of the elevon assembly at both stations 24" and 48".

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A complete tabulation of station, depth, spanwise location, and local skin thickness for all thermocouples is given in Table III. In addition, the wetted length from the tangency point is given for each T/C on the elevon.

TEST FACILITY DESCRIPTION

The NASA-Ames 3.5-Foot Hypersonic Wind Tunnel is a closed-circuit, blowdown-type tunnel capable of operating at nominal Mach numbers of 5, 7, and 10 at pressures to 1800 psia and temperatures to 3400°R for run times to four minutes. The major components of the facility include a gas storage system where the test gas is stored at 3000 psi, a storage heater filled with aluminum-oxide pebbles capable of heating the test gas to 3400°R, axisymmetric contoured nozzles with exit diameters of 42 inches for generating the desired Mach number, and a 900,000 ft^3 vacuum storage system which operates to pressures of 0.3 psia. The test section itself is an open-jet type enclosed within a chamber approximately 12 feet in diameter and 40 feet in length, arranged transversally to the flow direction.

A model support system is provided that can pitch models through an angle of attack range of -20 to +20 degrees, in a vertical plane, about a fixed point of rotation on the tunnel centerline. This rotation point is adjustable from 1 to 5 feet from the nozzle exit plane. The model normally is out of the test stream (strut centerline 37 inches from tunnel centerline) until the tunnel test conditions are established, after which it is inserted. Insertion time is adjustable to as little as 1/2 second, and models may be inserted at any strut angle.

A high-speed, analog-to-digital data acquisition system is used to record test data on magnetic tape. The present system is equipped to measure and record the outputs from 80 transducers in addition to 20 channels of tunnel parameters.

All test data were reduced at the NASA/Ames Research Center using the data reduction techniques outlined below. The thermocouple data were reduced using the one-dimensional, thin-wall equation:

$$\dot{q} = WCb \, \frac{dT_w}{dt} = h \left(H_{aw} - H_w \right) \equiv hH_t \left(\frac{H_{aw}}{H_t} - \frac{H_w}{H_t} \right) \tag{1}$$

which neglects heat-conduction losses.

Assuming that W and h are constant and

$$C = C_o + C_1 \, T_w + C_2 \, T_w^2 \text{ for } T_w \text{ ranges,} \tag{2}$$

the integration of equation (1) for $t = t_i$ to t and $T_w = T_{w_i}$ to T_w yields the linear equation:

$$f(T_w) = - \ell n \left(\frac{T_{aw}' - T_w}{T_{aw}' - T_{w_i}} \right) - \left[\frac{C_1}{C_{aw}'} + \frac{C_2}{C_{aw}'} \left(T_{aw}' + \frac{T_w + T_{w_i}}{2} \right) \right] (T_w - T_{w_i})$$

$$= \frac{hc_p}{WC_{aw}' b} \, (t - t_i) \tag{3}$$

where it is defined that:

$$T_{aw}' \equiv \frac{H_{aw}}{c_p} \equiv \frac{H_{aw}}{H_t} \, \frac{H_t}{c_p} \geq (T_{aw})_{PG} \tag{4}$$

$$C_{aw}' \equiv C_o + C_1 \, T_{aw}' + C_2 \, T_{aw}'^2 \tag{5}$$

≠ specific heat at adiabatic wall temperature

The form of Eq (3) is $f(T_w) = mt + a$ where m is the slope and a is the intercept for a straight line if heat-conduction errors are negligible. Thus, deviations from a straight line can indicate heat-conduction effects.

* Data Reduction Section provided by W. K. Lockman, ARC.

The slope, m, of $f(T_w)$ vs. t from Eq (3) is computed by a least-squares, straight-line fit over a finite time interval (approx. 1 sec.) beginning when the model reaches uniform tunnel flow. The value of the heat-transfer coefficient, h, is then determined from:

$$h = \frac{WC'_{aw}b}{c_p} m \qquad (6)$$

Using this value of h, the heat-transfer rate is evaluated at the initial time, t_i, when the model is isothermal at the initial wall enthalpy, H_{w_i}

$$\dot{q} = \dot{q}_i = h \left(H_{aw} - H_{w_i}\right) \equiv hH_t \left(\frac{H_{aw}}{H_t} - \frac{H_{w_i}}{H_t}\right) \qquad (7)$$

where H_{aw}/H_t is the same value used to evaluate h. The resultant value of $\dot{q}$ is independent of the value of H_{aw}/H_t used for both the h and q evaluations.

The reference sphere heating is also evaluated at the initial wall enthalpy by the method of Fay and Riddell (ref. 3):

$$\dot{q}_s = h_s \left(H_t - H_{w_i}\right) \equiv h_s H_t \left(1.0 - \frac{H_{w_i}}{H_t}\right) \qquad (8)$$

The model-to-sphere ratio of heat-transfer coefficients is then determined from Eqs. (7) and (8) as

$$\frac{h}{h_s} = \frac{\dot{q}_i}{\dot{q}_s} \left[\frac{1.0 - H_{w_i}/H_t}{H_{aw}/H_t - H_{w_i}/H_t}\right] \qquad (9)$$

where $\dot{q}_i$ is constant for all values of H_{aw}/H_t.

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To determine h/h_s for various values of H_{aw}/H_t, the particular value of H_{aw}/H_t is substituted into Eq. (9).

The Stanton number is defined as

$$St \equiv \frac{h}{\rho u} = \frac{q_i}{\rho u(H_{aw} - H_{w_i})} \tag{10}$$

where for free-stream conditions, $\rho u = \rho_\infty V_\infty$.

The calculations of the model heating, reference sphere heating, and Reynolds number included the corrections of NACA report 1135 (ref. 4) for calorically imperfect, thermally perfect air. Keyes' equation for viscosity (see ref. 5) was also used for the sphere heating and Reynolds number computations:

$$\mu = \frac{0.0232 \times 10^{-6} \ T^{0.5}}{1 + \frac{220}{T} \ 10^{-9/T}} \tag{11}$$

where the units for T and μ are °R and lb-sec/ft^2, respectively.

Test data are available through the following:

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Moffett Field, California 94035

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REFERENCES

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2. Grumman Aerospace Corporation Thermodynamics Report TPM-001-33, "Final Report Analysis and Evaluation - Elevon/Wing and Elevon/Elevon Gap Heating Wind Tunnel Test (Model 53-0)." By R. Bullis, L. Hemmerdinger and W. Timlen, March 1974.

3. Fay, J. A.; and Riddell, F. R.: Theory of Stagnation Point Heat Transfer in Dissociated Air. J. Aeron, Sci.; Vol. 25, No. 1, Feb. 1958, pp. 73-85.

4. Ames Research Staff: Equations, Tables, and Charts for Compressible Flow. NACA Rept. 1135, 1953.

5. Bertram, Mitchel H.: Comment on "Viscosity of Air." J. Spacecraft Rockets, Vol. 4, No. 2, Feb. 1967, pp. 287-288.

TABLE 1

TEST : OH44	NOMINAL TEST CONDITIONS		DATE :
MACH NUMBER	**REYNOLDS NUMBER** (per foot)	**DYNAMIC PRESSURE** (pounds/sq. inch)	**STAGNATION TEMPERATURE** (degrees Rankine)
5.1	0.7×10^6	3.065	2460
5.1	2.00×10^6	9.195	2460

BALANCE UTILIZED: _____

	CAPACITY:	ACCURACY:	COEFFICIENT TOLERANCE:
NF			
SF			
AF			
PM			
RM			
YM			

COMMENTS:

TABLE II.
ELEVON/ELEVON TEST CONDITIONS

Run	Elevon Station	Elevon Deflection	Elevon Gap	Elevon Gap Geometry	Tunnel P_t	Tunnel T_t	Re/Ft x 10^{-6}	Remarks
	In.	Degrees	In.		Psia	$^{\circ}$R		
1	24	0	.056	Parallel	107.08	1994.1	.72	Condensate on Model
1 Repeat	24	0	.056	"	106.71	2065.4	.68	
2	24	5	.056	"	101.28	1845.1	.78	
3	24	10	.056	"	101.24	1946.0	.71	
4	24	15	.056	"	100.88	2082.2	.63	
5	24	5/10	.056	"	100.71	2056.2	.65	Diff Defl(LH/RH)
6	24	0/15	.056	"	101.79	1899.8	.75	" " "
7	24	0/5	.056	"	100.68	2028.0	.66	" " "
8	24	5	.222	"	100.84	2001.4	.68	
9	24	10	.222	"	101.41	2022.7	.67	
10	24	15	.222	"	102.12	2010.3	.68	
11	24	15	.666	"	102.89	2006.8	.69	
12	24	10	.666	"	102.67	2016.6	.68	
13	24	5	.666	Parallel	101.57	2017.9	.67	
14	24	10	.666	20° Scarf	102.34	1891.8	.76	
15	24	10	.222	" "	103.97	1980.0	.71	
16	24	10	.056	" "	104.37	1949.4	.73	
17	24	15	.056	" "	105.61	2000.8	.71	
18	24	5	.056	20° Scarf	105.61	2021.3	.70	
19	24	5	.056	40° Scarf	103.79	2028.2	.68	
20	24	10	.056	" "	102.89	2033.7	.67	
21	24	15	.056	" "	104.35	2021.6	.69	
22	24	10	.222	" "	103.58	2018.8	.69	
23	24	10	.666	" "	103.44	2011.9	.69	
24	48	10	.666	" "	313.17	1925.6	2.25	
25	48	10	.222	" "	303.53	2100.1	1.88	
26	48	10	.056	" "	301.52	2024.1	1.99	
27	48	5	.056	" "	302.50	2042.5	1.97	
28	48	5	.056	20° Scarf	301.16	2017.4	2.00	
29	48	10	.056	" "	301.71	1982.3	2.06	
30	48	10	.222	" "	301.95	2020.1	2.00	
31	48	5/10	.222	" "	301.53	2056.3	1.94	Diff Defl-Scarf
32	48	5/10	.222	" "	301.35	2045.7	1.95	" Down
33	48	10	.666	" "	300.74	2028.3	1.98	
34	48	10	.666	Parallel	301.23	1974.9	2.07	
35	48	5	.666	"	302.87	2024.7	2.00	
36	48	5	.222	"	302.44	2064.5	1.93	
37	48	10	.222	"	301.77	2059.7	1.93	
38	48	10	.056	"	302.26	2059.3	1.94	
39	48	5	.056	"	303.23	2017.6	2.01	
40	48	0	.056	"	303.05	2012.1	2.02	
41	48	0/5	.056	"	303.12	2041.3	1.97	
42	48	0/10	.056	"	302.99	2030.5	1.99	
43	48	5/10	.056	"	303.48	2029.9	1.99	Diff Defl-Scarf Up
44	48	10/5	.222	20° Scarf	302.39	1985.8	2.06	"
45	48	10/0	.222	" "	300.50	2014.9	2.00	"
46	48	5/0	.222	" "	303.67	2059.3	1.95	"

TABLE III. – ELEVON/ELEVON GAP MODEL THERMOCOUPLE LOCATIONS

Thermocouple No.	Station		Depth	Spanwise Location	Skin Thickness	Wetted Length
	Inches from Carrier L.E.		Inches from Carrier Top	Inches from Carrier ₵ (Right +/Left -)	Inches	Inches from Tangency Pt. (Forward - Aft +)
	@ STA 24	@ STA 48				
101	24.03	48.03	.555	-.493	.0081	-.854
102	24.11	48.11	.385	-.493	.0077	-.678
103	24.22	48.22	.175	-.493	.0077	-.550
104	24.26	48.26	.115	-.493	.0072	-.489
105	24.31	48.31	.085	-.493	.0150	-.428
106	24.36	48.36	.070	-.493	.0152	-.364
107	24.41	48.41	.040	-.493	.0160	-.305
108	24.47	48.47	.020	-.493	.0159	-.244
109	24.52	48.52	.015	-.493	.0160	-.183
110	24.58	48.58	.010	-.493	.0160	-.122
111	24.64	48.64	.003	-.493	.0158	-.061
112	24.7	48.7	0	-.493	.0157	0
113	24.8	48.8	0	-.493	.0160	+.1
114	24.9	48.9	0	-.493	.0163	.2
115	25.1	49.1	0	-.493	.0162	.4
116	25.4	49.4	0	-.493	.0160	.7
117	25.7	49.7	0	-.493	.0158	1.0
118	26.1	50.1	0	-.493	.0160	1.4
119	26.6	50.6	0	-.493	.0157	1.9
120	27.1	51.1	0	-.493	.0153	2.4
121	27.6	51.6	0	-.493	.0153	2.9
122	28.1	52.1	0	-.493	.0155	3.4
123	28.6	52.6	0	-.493	.0154	3.9
124	29.1	53.1	0	-.493	.0152	4.4
125	29.6	53.6	0	-.493	.0152	4.9
126	24.03	48.03	.555	.493	.0080	-.854
127	24.11	48.11	.385	.493	.0075	-.678
128	24.22	48.22	.175	.493	.0072	-.550
129	24.26	48.26	.115	.493	.0072	-.489
130	24.31	48.31	.085	.493	.0150	-.428
131	24.36	48.36	.070	.493	.0160	-.364
132	24.41	48.41	.040	.493	.0161	-.305
133	24.47	48.47	.020	.493	.0164	-.244
134	24.52	48.52	.015	.493	.0162	-.183
135	24.58	48.58	.010	.493	.0161	-.122
136	24.64	48.64	.003	.493	.0160	-.061
137	24.7	48.7	0	.493	.0161	0
138	24.8	48.8	0	.493	.0160	+.1
139	24.9	48.9	0	.493	.0161	.2
140	25.1	49.1	0	.493	.0162	.4
141	25.4	49.4	0	.493	.0157	.7
142	25.7	49.7	0	.493	.0154	1.0
143	26.1	50.1	0	.493	.0153	1.4
144	26.6	50.6	0	.493	.0153	1.9
145	27.1	51.1	0	.493	.0162	2.4
146	27.6	51.6	0	.493	.0152	2.9
147	28.1	52.1	0	.493	.0161	3.4

TABLE III. - ELEVON/ELEVON GAP MODEL THERMOCOUPLE LOCATIONS (Continued)

Thermocouple No.	Station		Depth	Spanwise Location	Skin Thickness	Wetted Length
	Inches from Carrier L.E.		Inches from Carrier Top	Inches from Carrier ₵	Inches	Inches from Tangency Pt. (Forward – Aft +)
	@ STA 24	@ STA 48		(Right +/Left -)		
148	28.6	52.6	0	.493	.0152	3.9
149	29.1	53.1	0	.493	.0152	4.4
150	29.6	53.6	0	.493	.0160	4.9
151	23.07	47.09	0	-.50	.0150	
152	23.93	47.93	0	-.50	.0140	
153	24.12	48.12	0	-.50	.0140	
154	24.32	48.32	0	-.50	.0140	
155	24.40	48.40	.056	-.50	.0140	
156	24.32	48.32	.112	-.50	.0140	
157	24.16	48.16	.155	-.50	.0060	
158	24.04	48.04	.310	-.50	.0060	
159	23.95	47.95	.510	-.50	.0060	
160	23.94	47.94	.940	-.50	.0060	
161	23.07	47.09	0	.515	.0150	
162	23.93	47.93	0	.515	.0140	
163	24.12	48.12	0	.515	.0140	
164	24.32	48.32	0	.515	.0140	
165	24.40	48.40	.056	.515	.0140	
166	24.32	48.32	.112	.515	.0140	
167	24.16	48.16	.155	.515	.0060	
168	24.04	48.04	.310	.515	.0060	
169	23.95	47.95	.510	.515	.0060	
170	23.94	47.94	.940	.515	.0060	
1	12.55	24.55	0	0	.0158	
2	13.5	25.5	0	0	.0151	
3	15.505	27.505	0	0	.0150	
4	16.5	28.5	0	0	.0151	
5	17.45	29.45	0	0	.0156	
6	-	30.55	0	0	.0149	
7	-	31.5	0	0	.0127	
8	-	33.505	0	0	.0133	
9	-	34.5	0	0	.0153	
10	-	35.45	0	0	.0160	
11	-	36.55	0	0	.0132	
12	-	37.5	0	0	.0130	
13	-	39.505	0	0	.0109	
14	-	40.5	0	0	.0125	
15	-	41.45	0	0	.0138	
16	18.55	42.55	0	0	.0137	
18	21.27	45.27	0	0	.0138	
19	22.19	46.19	0	0	.0142	

TABLE III. – ELEVON/ELEVON GAP MODEL THERMOCOUPLE LOCATIONS (Continued)

Thermocouple No.	Station		Depth	Spanwise Location	Skin Thickness
	Inches from Carrier L.E.		Inches from Carrier Top	Inches from Carrier ₵	Inches
	@ STA 24	@ STA 48		(Right + Left -)	
171	25.7	49.7	0	-.793	.0158
172	25.7	49.7	0	-.693	.0158
173	25.7	49.7	0	-.593	.0158
174	27.6	51.6	0	-.793	.0153
175	27.6	51.6	0	-.693	.0153
176	27.6	51.6	0	-.593	.0153
177	24.5	48.5	.43	-.893	.0071
178	24.6	48.6	.38	-.893	.0072
179	24.7	48.7	.35	-.893	.0073
180	24.9	48.9	.35	-.893	.0075
181	25.1	49.1	.35	-.893	.0075
182	25.4	49.4	.35	-.893	.0076
183	25.6	49.6	.30	-.893	.0078
184	26.0	50.0	.30	-.893	.0077
185	26.75	50.75	.30	-.893	.0077
186	27.15	51.15	.30	-.893	.0077
187	27.45	51.45	.30	-.893	.0077
188	28.25	52.25	.35	-.893	.0077
189	28.5	52.5	.35	-.893	.0076
190	29.2	53.2	.30	-.893	.0070
191	29.45	53.45	.35	-.893	.0069
192	26.75	50.75	.60	-.893	.0077
193	27.15	51.15	.60	-.893	.0077
194	27.15	51.15	.90	-.893	.0076
195	28.25	52.25	.60	-.893	.0076
196	28.5	52.5	.60	-.893	.0076
197	28.5	52.5	.90	-.893	.0077
198	29.45	53.45	.60	-.893	.0069
199	25.6	49.6	.05	-.893	.0078
200	25.6	49.6	.10	-.893	.0078
201	25.6	49.6	.20	-.893	.0076
202	25.6	49.6	.40	-.893	.0075
203	25.6	49.6	.50	-.893	.0076
204	25.6	49.6	.60	-.893	.0076
205	25.6	49.6	.70	-.893	.0075
206	25.6	49.6	.80	-.893	.0075
207	25.6	49.6	.90	-.893	.0075
208	27.45	51.45	.05	-.893	.0078
209	27.45	51.45	.10	-.893	.0078
210	27.45	51.45	.20	-.893	.0078
211	27.45	51.45	.40	-.893	.0077
212	27.45	51.45	.50	-.893	.0077
213	27.45	51.45	.60	-.893	.0077
214	27.45	51.45	.70	-.893	.0077
215	27.45	51.45	.80	-.893	.0077
216	27.45	51.45	.90	-.893	.0077

TABLE III. – ELEVON/ELEVON GAP MODEL THERMOCOUPLE LOCATIONS (Continued)

Thermocouple No.	Station		Depth	Spanwise Location	Skin Thickness
	Inches from Carrier L.E.		Inches from Carrier Top	Inches from Carrier ₵	Inches
	@ STA 24	@ STA 48		(Right + Left -)	
217	29.2	53.2	.05	-.893	.0071
218	29.2	53.2	.10	-.893	.0071
219	29.2	53.2	.20	-.893	.0071
220	29.2	53.2	.40	-.893	.0070
221	29.2	53.2	.50	-.893	.0070
222	29.2	53.2	.60	-.893	.0070
223	29.2	53.2	.70	-.893	.0070
224	29.2	53.2	.80	-.893	.0069
225	29.2	53.2	.90	-.893	.0069
251	29.44	53.44	.53	-1.130*	.0071
252	29.2	53.2	.53	-1.130*	.0070
253	28.5	52.5	.53	-1.130*	.0068
254	28.25	52.25	.53	-1.130*	.0068
255	27.45	51.45	.53	-1.130*	.0070
256	27.15	51.15	.53	-1.130*	.0063
257	26.78	50.78	.53	-1.130*	.0063
258	26.0	50.0	.53	-1.130*	.0070
259	29.2	53.2	.85	-1.240*	.0073
260	29.2	53.2	.75	-1.206*	.0070
261	29.2	53.2	.65	-1.171*	.0070
262	29.2	53.2	.45	-1.103*	.0070
263	29.2	53.2	.33	-1.062*	.0070
264	29.2	53.2	.21	-1.021*	.0071
265	27.45	51.45	.85	-1.240*	.0068
266	27.45	51.45	.75	-1.206*	.0069
267	27.45	51.45	.65	-1.171*	.0069
268	27.45	51.45	.45	-1.103*	.0070
269	27.45	51.45	.33	-1.062*	.0070
270	27.45	51.45	.21	-1.021*	.0072
271	29.44	53.44	.65	-1.367**	.0072
272	29.2	53.2	.65	-1.367**	.0070
273	28.5	52.5	.65	-1.367**	.0070
274	28.25	52.25	.65	-1.367**	.0070
275	27.45	51.45	.65	-1.367**	.0073
276	27.15	51.15	.65	-1.367**	.0069
277	26.78	50.78	.65	-1.367**	.0073
278	26.0	50.0	.65	-1.367**	.0074
279	29.2	53.2	.26	-1.116**	.0070
280	29.2	53.2	.39	-1.200**	.0071
281	29.2	53.2	.52	-1.284**	.0071
282	29.2	53.2	.78	-1.451**	.0071
283	29.2	53.2	.91	-1.534**	.0070
284	29.2	53.2	1.04	-1.618**	.0070
285	27.45	51.45	.26	-1.116**	.0073
286	27.45	51.45	.39	-1.200**	.0073
287	27.45	51.45	.52	-1.284**	.0073

* 20° Scarf - Dependent on gap width being tested - distance for .056" gap given.
** 40° Scarf - Dependent on gap width being tested - distance for .056" gap given.

TABLE III. - ELEVON/ELEVON GAP MODEL THERMOCOUPLE LOCATIONS (Concluded)

Thermocouple No.	Station		Depth	Spanwise Location	Skin Thickness
	Inches from Carrier L.E.		Inches from Carrier Top	Inches from Carrier C_L (Right + Left -)	Inches
	@ STA 24	@ STA 48			
288	27.45	51.45	.78	-1.451**	.0073
289	27.45	51.45	.91	-1.534**	.0073
290	27.45	51.45	1.04	-1.618**	.0073
1	12.55	36.55	0	0	.0158
2	13.5	37.50	0	0	.0151
3	15.05	39.05	0	0	.0150
4	16.5	40.50	0	0	.0151
5	17.45	41.45	0	0	.0156

** 40° Scarf - Dependent on gap width being tested - distance for .056" gap given.

INSTRUMENTED ELEVON INSERT MAY
ALSO BE LOCATED WITH HINGE LINE
24" AND 36" AFT PLATE LEADING
EDGE

48"

27.000"
(68.58 cm)

24.000"
(60.96 cm)

42.000"
(106.68 cm)

12.00
(30.48 cm)

2.000
(5.08 cm)

INSTRUMENT
CONNECTIONS

92.379"
(234.643 cm)

60.000"
(152.40 cm)

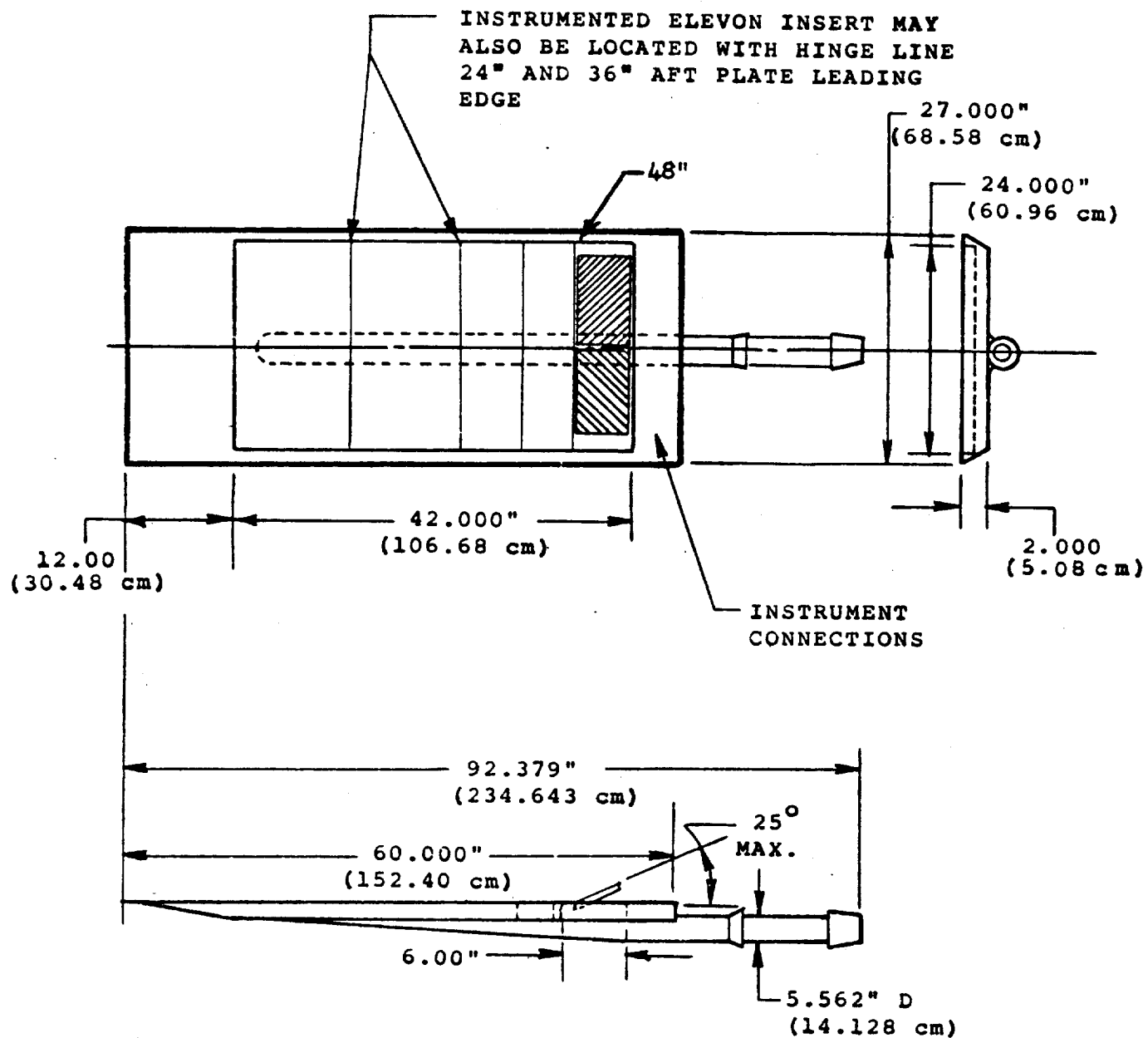25°
MAX.

6.00"

5.562" D
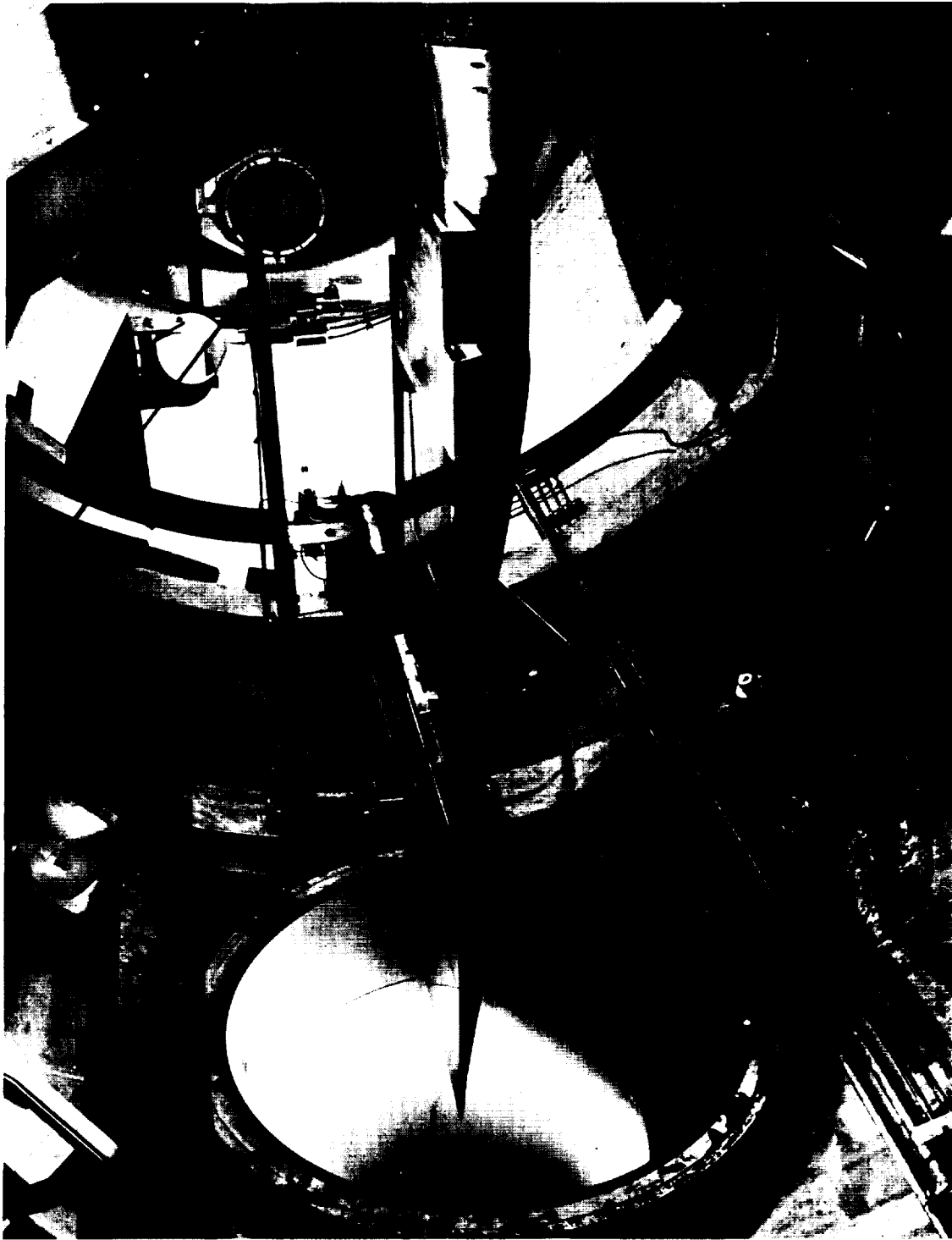(14.128 cm)

Figure 1. - Carrier Plate

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Figure 2. - Model Installed In Tunnel With Elevon at Station 24.